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INSTRUCTION MANUAL
OPTICAL EFFECTS MODULE
MODEL OEM

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FIGURE 1 OPTICAL EFFECTS MODULE, TOP VIEW

FIGURE 2 OPTICAL EFFECTS MODULE, SIDE VIEW

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1) GENERAL DESCRIPTION OF THE INSTRUMENT

The Optical Effects Module Model OEM-1 is a laboratory prototype instrument designed for the automated measurement of radiation transmission and scattering through optical samples. The system comprises two main components: the Optical Effects Module Enclosure (OEME) and the Optical Effects Module Electronic Controller and Processor (OEMCP). These two subsystems will be described in two different sections of this Instruction Manual.

The OEM is designed for operation in the near UV at approximately 2540 Å, corresponding to the most intense spectral line activated by the mercury discharge lamp used for illumination. The radiation from this source is detected in transmission and reflection through a number of selectable samples. The basic objective of this operation is to monitor in real time the accretion of possible contamination on the surface of these samples. The projected function will be carried out in the future in the Space Shuttle environment.

The optical samples are exposed outside of the OEME proper to define exposure conditions and to separate exposure and measurement environments. Changes in the transmissivity of the samples are attributable to surface contamination or to bulk effects due to radiation. Surface contamination will increase radiation scattering due to Rayleigh-Gans effect or to other phenomena, depending on the characteristic size of the particulate contaminants. Thus, also scattering from the samples becomes a part of the measurement program.

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The determination of these two effects calls for precision transmission and scattering measurements. Hence, the optical beam generated in the OEME is modulated by a chopper wheel to allow synchronous detection under favorable signal-to-noise conditions. This mode of operation entails sampling the signal at each position for a certain length of time to generate statistically significant data. The sequence of this sampling is controlled at the panel of the OEMCP. This instrument acquires also the intensity transmitted with no sample in place, I_0 , and displays automatically the ratio of attenuated intensity normalized to I_0 . An intermediate external synchronous amplifier is required for this automated operation. The parameters measured are available on a digital display and also on a rear panel output in BCD format for storage on magnetic tape or printer.

The two subsystems are connected by a cable. The OEME and OEMCP, in the present form, feature weights of 9 kg and 5 kg, respectively.

II) OPTICAL EFFECTS MODULE ENCLOSURE

The OEME is designed as a lightweight and rigid configuration. The laboratory prototype features simplicity of assembly and flexibility for possible restructuring during the testing program to be conducted at the GCMSCC.

The enclosure is a box of dimensions $28 \times 27 \times 16 \text{ cm}^3$ assembled of high strength 6 mm thick aluminum plate (6061-T6) bolted together with stainless steel screws. Top and bottom lids are also bolted together in place and these are readily removable for inspection of the functioning of installed components.

The enclosure is hard black anodized to avoid stray radiation from the walls. All the surfaces are machined to microfinish quality.

Electrical wires are fed through a lateral wall of the OEME via a plug. An interconnecting cable is used to interface the OEME with the OEMCP.

Light source with chopper motor and also the sample stepping motor are located outside the OEME to eliminate the possibility of contamination due to effusion from these devices.

The OEME is provided with four aluminum pedestals of 25 mm diameter and 9 cm height. These pedestals facilitate positioning and handling of the instrument during testing. The overall outer dimensions of the OEME including pedestals amount to $32 \times 43 \times 25 \text{ cm}^3$.

III) LIGHT SOURCE SUBSYSTEM AND MODULATOR

The illumination of the samples is provided by a low pressure, cold cathode mercury vapor discharge lamp. A double bore tubing of fused quartz contains the active plasma medium and limits transmission to wavelengths longer than 1800 Å. This interface is not impairing the radiance of the source, since the principal output is due to the Hg I line at 2536.52 Å, which is the dominant transition. The bremsstrahlung background and other lines contribute to only 8% of the total irradiance. The lamp selected by NASA for this application is the Pen-ray Model 11-SC-1 by Ultraviolet Products, Inc. with a bulb length of 50 mm and a tube diameter of 6 mm. The nominal short wavelength radiant intensity is 3.6 mW/cm² with a lamp current of 10 mA.

The lamp is located near the focal point of a quartz collimating lens. A slight beam divergence is introduced to improve illumination of the samples and to decrease the intensity at the photomultiplier.

The lamp requires a starting voltage of 800 V and an operating voltage of 270 V. These outputs in combination with the current of 20 mA are provided by a Pen-ray Power Supply Model No. SCT-1.

A miniature 10 W DC motor is used to drive a chopper blade located in front of the lamp. The disc of this blade features two apertures with equalized "on-off" sectors designed to obtain a 50% modulation cycle. The disc has also been hard-coat anodized to absorb scattered radiation and to eliminate returns from the sample. A LED-photo-transistor aggregate is located peripherally around the chopper disc to generate a

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synchronizing signal for the reference to the lock-in phase sensitive amplifier. The reference signal is available at the front panel of the OEMCP by means of BNC connector.

The modulating frequency has been chosen at around 15 Hz and a certain amount of frequency adjustment is possible with the electronic circuitry.

IV) OPTICAL SYSTEM OF OEM

The radiant energy generated by the mercury discharge lamp is collected by a quartz lens with a focal length of 50 mm. The diameter of the lens is 25 mm with an aperture of F:2.

The purpose of this lens is to collimate the beam into the optical sample in order to generate a relatively even distribution of the light intensity. Clearly, this is not really the case, since the source is of linear dimensions rather than a point source. However, the optical element reduces divergence of the beam, which is of the essence.

Furthermore, collimation is also important to match the beam diameter to the size of the photomultiplier cathode entrance. This diameter amounts to 6.4 mm, thus the choice of the 25 .4 mm aperture is more than ample.

A second part of the optical subsystem includes the aggregate for the measurement of the light intensity scattered by one sample. The scattered radiation is collected by a glass ellipsoid with first surface aluminized coating. The ellipsoid has a major diameter of 122 mm and a depth of 50 mm. Thus, some of the scattered radiation will be collected into a spot approximately 35 mm above the midplane of the sample. This scattered radiation is further lightguided through two reflective planes into the photomultiplier. For this purpose, an aluminum lightguide is used, similar to the lightguides developed at ADKIN over the past ten years. The surfaces of the lightguide are diffusely brightened to achieve good reflectivity in the region of 2500 Å, where 92% of the total irradiance is generated. This by-pass lightguide is required only for the reflective

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sample. The lightguide proper is installed at a fixed position above the plane of the photomultiplier. A second part of this subsystem deflects the radiation from a vertical into a horizontal direction. This deflector is solidly attached to the sample wheel and it is moved into a matching position once every revolution. Thus, the radiation scattered by the sample is first collected by the ellipsoidal mirror and entered into the aperture of the lightguide, then deflected from the downward into a transverse direction to impinge against the face of the photomultiplier. This mechanism is simple and does not require additional power for sequencing or for activating.

Details of the configuration are presented in two enclosed drawings.

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V) SAMPLE HOLDER SUBSYSTEM

The sample holder features a carousel configuration with eight sample positions. The wheel of the carousel is an aluminum disc of 240 mm diameter and of 6 mm thickness fastened to a spindle and aligned with the axis of a stepping motor.

The stepping motor increments the angular position in intervals of 15° . Hence, three steps correspond to an angular interval of 45° , which is the displacement between adjacent samples. The stepping motor is programmed in selectable or sequential fashion at the control panel of the OEMCP. The position is determined by a coding-decoding electro-optical system located around the rim of the sample wheel. Thus, a certain measurement cycle can be started with a given zero position, corresponding to an empty sample to which all other readings can be normalized.

The samples are installed on optical mounts which are precision located on the wheel. The spacing is $45^\circ \pm 10$ arc minutes. Individual optical mounts are used instead of a wheel with a heavy rim. This scheme allows considerable saving in weight which is of basic importance for flight hardware. The second consideration entails simplification of the alignment and installation. Furthermore, in eliminating the heavy rim, we have also reduced somewhat the width of the two slots designed for the passage of the samples into the open.

We have selected a 24 V motor for energizing the wheel and for interfacing with the 28 VDC available on board of the Space Shuttle. The net starting or breakaway torque is approximately 700 N-mm (100 oz-in) with a step input of about 1700 A-turns.

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The power consumption is about 85 W under continuous operation and substantially less, if the dwell-time at each position is correspondingly lengthened.

The samples are thus located with a precision of $\pm 1^\circ$ non-accumulative error by means of the stepping motor.

VI) RADIATION DETECTOR SUBSYSTEM

The radiation transmitted through or scattered by the samples will be detected by a solar-blind photomultiplier of the EMR Model 510-09-13 with 13 CuBe dynodes.

The mount for this photodiode is integrated in the wall structure of the OEME. Thus, the detector is completely independent of the spinning wheel and maintains its position during the rotation. The mount comprises a plate tightened to the enclosure wall by two stainless steel bolts. In turn, two plates with appropriate holes and adjustable clamps support the photomultiplier and align the same with respect to the optical axis of the system.

The wiring to the photomultiplier is ducted laterally, thus avoiding every contact with the spinning wheel.

If a different phototube should be selected instead of the present one, we have made allowance for a total length of 100 mm and a diameter up to 50 mm. Hence, the geometry can accommodate the photodiode EMR Model 543P-09-00, if the downward support plates are bored to an accordingly larger diameter.

The EMR photomultiplier features an end-on configuration and it is thus readily aligned with the optical axis. The tube has a MgF window of 6.4 mm diameter with a semitransparent CsTe photocathode. The MgF extends the spectral sensitivity into the 1150 Å range and peak sensitivity occurs at 2540 Å, which is an excellent match to the emission of the Hg λ line at 2536.5 Å. At such wavelength, the typical quantum efficiency will be approximately 7%, corresponding to a cathode radiant sensitivity of 0.014 A/W.

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The photomultiplier requires a supply voltage of 3000 V maximum with a peak anode current of 10 μ A. This supply was provided by the NASA agency together with the selected phototube. The supply is installed immediately above the plane of the photomultiplier. Thus, only low voltage leads need to be ducted to the input and the length of the high voltage wires is minimized.

The high voltage is set for the minimum value obtainable at the output of the EMR power supply, and this amounts to approximately 875 V. Furthermore, the anode current is also limited to less than 10 μ A. In spite of these precautions, and since the irradiance at the photocathode may be rather intense, we advise the user to exert the utmost precaution in handling this part of the system. Appropriate neutral density or interferential filters should be introduced in the initial measurements to avoid burn-up of the delicate photocathode or other damage to the tube.